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COMBUSTION OF HUMAN WASTE
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COMBUSTION OF HUMAN WASTE AND PRODUCT RECOVERY*

INTRODUCTION

The study on the kinetics of combustion of volatilized wastes was continued. A new method of CO_2 analysis was tried and proved more satisfactory than the Orsat Apparatus. The new method employs the chemical reaction: $\text{Ba}(\text{OH})_2 + \text{CO}_2 = \text{BaCO}_3 + \text{H}_2\text{O}$. The amount of $\text{Ba}(\text{OH})_2$ which reacts with CO_2 is determined by back filtration with oxalic acid, using phenolphthalein as the indicator. Algal growth studies (Chlorella) with the ash from the volatilization chamber were continued.

An exhaust system was installed to remove the health hazard and reduce the nuisance conditions which existed when the combustion chamber is non-operative or operating at low efficiency. It is anticipated to obtain data on the kinetics of volatilization of human wastes with the combustion chamber functioning over a wide range of efficiencies. The information obtained will enable prediction of needed capacity (size) for any specified loading, operating conditions and efficiency. The data obtained to date on the kinetics have served only to delineate the desirable operating conditions which will yield meaningful results.

LABORATORY WORK

Additional information on the relationship between residual weight and oxygen supply, and between residual carbon and oxygen supply was obtained with the volatilization chamber operated at 200°C .

The differences in solubility of the residue after ignition in a muffle furnace and in the volatilization chamber were investigated further.

A series of experiments to determine the growth characteristics of Chlorella on the residue was undertaken. In particular, the ratio of the concentration of urea to residue at which some nutrient in the ash became limiting was determined. Studies of the maximum concentration of the residue which will be tolerated by the algae and the recovery of the carbon and nitrogen by the algae are presently under way.

*This research was conducted in accordance with the "Principles of Laboratory Animal Care" of the National Society for Medical Research.

RESULTS AND DISCUSSION

Table I shows the characteristics of the raw urine and feces mixture used. The residual weight and carbon content of the residue with respect to time are summarized in Table II for the volatilization chamber operated at 200° C and a 7.56-l/m rate of air supply. A comparison of the solubility, both in distilled water and 0.02 N-HCl, of the muffle furnace and volatilization chamber residue are given in Tables III(a) and III(b). Algal growth information is tabulated in Tables IV(a) to IV(e) and Table V.

The characteristics of the raw urine and feces mixture were very similar to those reported previously. The carbon content with respect to time indicates that a relatively short period of high temperature is sufficient to volatilize the waste, provided the waste is in a predried state. From the standpoint of waste disposal, it may suffice in certain cases to reduce the carbon content of the waste to less than 40 per cent.

The solubility of the residue varies for different raw samples, as shown. The data indicate also that the solubility of the muffle furnace residue is approximately the same as the solubility of the volatilization chamber residue, provided that oxidation is relatively complete. At 400° C, a 60-minute oxidation period is sufficient for carbon reduction of <90%. At 300° C, a 60-minute oxidation period is insufficient for complete oxidation. A comparison of the solubility data at 300° C and 400° C shows that the weight of soluble material increases with the degree of oxidation of the organic matter in the waste. This substantiates earlier observations and would indicate that the organic compounds contain a moderate amount of inorganic elements other than oxygen and hydrogen which are converted into soluble salts when the compounds are oxidized. Another possible explanation is that some of the soluble material is absorbed by the organic compounds in unoxidized waste and cannot be extracted easily by solvents used in the solubility test.

As shown in Table IV(b), algal growth was not supported by a carbon and nitrogen source alone. The greater growth rate exhibited by cultures with EDTA, Table IV(a), indicates that some salt toxicity was exerted by the residue initially. The final population concentration of algae was unaffected by either the presence or absence of EDTA.

The cultures aerated with 1% and 3% CO₂ gave a limiting algal population of 1 to 2×10^8 cells/ml per 100 mg/l of residue. The weight ratio of urea to residue corresponding to the limiting population was ≥ 0.3 .

TABLE I
CHARACTERISTICS OF RAW SAMPLES OF URINE AND FECES¹

Sample	% Carbon ² dry basis	% Solids ³ wet basis	C/A ⁴ dry basis	C/V ⁵ dry basis
E	45.1	3.80	4.27	0.504
F	42.3	3.90	2.73	0.499
G	43.9	3.93	4.36	0.488
Average	43.8	3.88	3.79	0.497

¹ Each entry in the table represents the arithmetic average of two to four determination.

² Per cent carbon by weight was determined from carbon and hydrogen analysis.

³ Per cent solids by weight was determined by drying at 103° C.

⁴ The weight ratio of carbon/ash was determined at 850° C.

⁵ The weight ratio of carbon to volatile matter was determined at 850° C.

TABLE II
WEIGHT AND CARBON REMAINING VS TIME

200° C, 7.56 l/m air supply, 2 gm sample E						
Item	Time (minutes)				Additional time at 600° C (minutes)	
	20	80	240	420	7	20
Weight Remaining, per cent	88.4	78.4	74.8	71.8	17.7	11.5
Carbon Remaining, per cent	91.2	88.5	87.9	75.5	14.2	0.68

TABLE III(a)
SOLUBILITY OF RESIDUE, MUFFLE FURNACE*

Raw Sample	Temperature, °C	Time of Ignition, min.	Solubility, 0.02N-HCl	Solubility, Distilled Water
E	300	60	0.041	0.031
E	400	60	0.075	0.020
E	400	60	0.077	0.039
F	400	60	0.216	0.173

* Solubility is expressed in gm dissolved per gm raw sample.

TABLE III(b)
SOLUBILITY OF RESIDUE, VOLATILIZATION CHAMBER*

Raw Sample	Temperature °C	Air Supply, l/m	Time of Ignition, min.	Solubility, 0.02N-HCl	Solubility, Distilled Water
E	300	15.1	60	0.015	0.006
E	400	15.1	60	0.070	0.030
E	400	15.1	60	0.077	0.033
E	400	29.7	60	0.076	0.036
E	400	29.7	60	0.074	0.039
E	400	29.7	30	0.026	0.018
F	400	15.1	60	0.204	0.167
F	400	29.7	60	0.172	0.127

* Solubility is expressed in gm dissolved per gm raw sample

TABLE IV(a)

ALGAL GROWTH ON RESIDUE

(un-aerated batch cultures)

Culture Number	Components of Medium			Cell Counts $\times 10^6$		Time of Culture (days)	Generation Time (days)
	Residue (mg/l)	Dextrose (mg/l)	EDTA (mg/l)	Urea (mg/l)	Initial (cells/ml)	Final (cells/ml)	
1-1	100	10	—	10	2.00	17.3	2.28
2	1000	10	—	10	12.1	9.55	No Growth
3	5000	10	—	10	1.98	0.88	No Growth
4	100	10	10	10	1.87	10.7	2.89
5	1000	10	10	10	3.62	8.04	6.31
6	5000	10	10	10	1.77	1.94	1.28

TABLE IV(b)
ALGAL GROWTH ON RESIDUE
(unaerated batch cultures)

Culture Number	Components of Medium			Initial Cell Count (cells/ml)	Generations, at Plateau
	Residue (mg/l)	Dextrose (mg/l)	Urea (mg/l)		
II-1	—	10	10	6.35×10^4	No Growth
2	—	10	10	6.35×10^4	No Growth
3	—	10	10	1.06×10^5	No Growth
4	100	10	10	8.46×10^4	7.23
5	100	10	10	8.46×10^4	
6	200	10	10	1.06×10^5	7.51
7	200	10	10	1.06×10^5	

TABLE IV(c)
ALGAL GROWTH ON RESIDUE
(aerated batch cultures, 1% CO₂)

Culture Number	Components of Medium			Initial Cell Count (cells/ml)	Generations, at Plateau
	Residue (mg/l)	Urea (mg/l)	EDTA (mg/l)		
III-1	30	10	—	3.58×10^5	5.70
2	30	10	—	4.09×10^5	5.72
3	30	10	10	3.67×10^5	6.37
4	30	10	10	3.67×10^5	6.14
5	30	—	10	3.16×10^5	No Growth
6	30	—	10	3.16×10^5	No Growth

TABLE IV(d)

ALGAL GROWTH ON RESIDUE

(aerated batch cultures, 3% CO₂)

Culture Number	Components of Medium Residue (mg/l)	Urea (mg/l)	Initial Cell Count (cells/ml)	Generations, at Plateau
IV-1	1000	3	1.06×10^5	7.82
2	1000	10	1.27×10^5	7.88
3	1000	30	8.46×10^4	9.64
4	1000	100	8.46×10^4	12.0
5	1000	300	8.46×10^4	13.5
6	1000	1000	8.46×10^4	14.1

TABLE IV(e)

ALGAL GROWTH ON RESIDUE

(aerated batch cultures, 3% CO₂)

Culture Number	Components of Medium Residue (mg/l)	Urea (mg/l)	Initial Cell Count (cells/ml)	Generations, at Plateau
V-1	100	30	4.42×10^5	8.16
2	100	100	3.58×10^5	8.56
3	100	300	4.00×10^5	8.09
4	100	1000	3.58×10^5	8.23
5	100	3000	3.16×10^5	8.46
6	100	10,000	3.78×10^5	9.16

TABLE V
MAXIMUM ALGAL CONCENTRATION
(aerated batch cultures, 3% CO₂)

Culture Number	Urea/Residue (wt. basis)	Maximum Algal Concentration (cells/ml)
IV-1	0.003	2.48×10^7
1000 mg/l Residue	2	3.12×10^7
	3	7.05×10^7
	4	3.69×10^8
	5	1.04×10^9
	6	1.57×10^9
V-1	0.30	1.33×10^8
100 mg/l Residue	2	1.42×10^8
	3	1.13×10^8
	4	1.11×10^8
	5	1.15×10^8
	6	2.24×10^8